cedure" (pag. 47) it could be erroneously understood that the minimization procedure can find a global minimum, while, in general, only a local minimum can be guaranteed.

An approximation of the slip surface by fixing the abscissas of the vertices is clearly less good. But in general the difference between the safety factors evaluated by the pattern search method and the method of Arai and Tagyo is very small and technically negligible. For example, for the slope reported by the authors in Fig. 5 (pag. 47), the critical surface in Fig. 17 is found by the pattern search method. The coordinates of a trial surface and the critical surface are reported in Table 2.

This surface appears very similar to the that of the authors and the computed safety factor (1.620) is pratically the same.

I am of the opinion that the method proposed by Arai and Tagyo represents a substantial improvement on the alternating variables method, since it enables the known limitations of the latter to be overcome. However it does lack some of the advantages typical of gradient methods with respect to direct search ones.

Finally, the most important limit of the method proposed is that it can only be applied to the Janbu simplified method, whereas the pattern search method enables the safety factor to be computed with any stability method whatsoever.

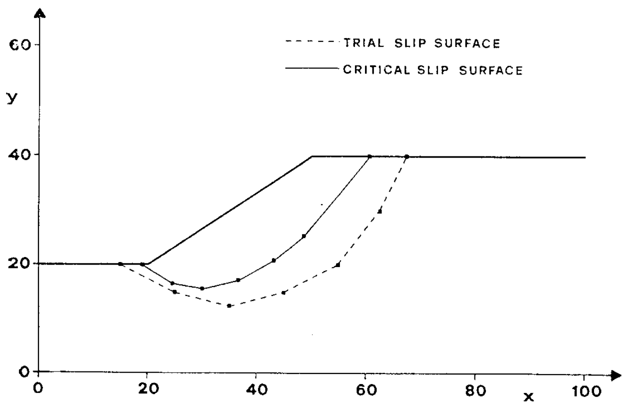

Fig. 17.

Table 2. Coordinates of trial surface and critical surface found by the pattern search method

Trial surface		Critical Surface	
x	y	x	y
15.0	20.0	18.9	20.0
25.0	15.0	24.4	16.6
35.0	12.5	30.0	15.7
45.0	15.0	36.6	17.1
55.0	20.0	43.1	20.7
62.5	30.0	48.5	25.3
67.5	40.0	60.5	40.0

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EVALUATION OF EARTHQUAKE-INDUCED SLIDING IN ROCKFILL DAMS*

Closure by Hiroyuki Watanabe**, Seishirō Satō*** and Kyōko Murakami***

The writers would like to thank Dr. M. Kikusawa and Prof. T. Hasegawa for their discussion.

As for the first problem in the discussion, concerning possibility of the potential slide passing through the central core, the writers pointed out lots of its possibility in the paper as shown in Fig. 4. All potential sliding circles estimated from all analyzed cases shown in Table 1 were superimposed in Fig. 17, and it is obviously recognized that all of these cir-

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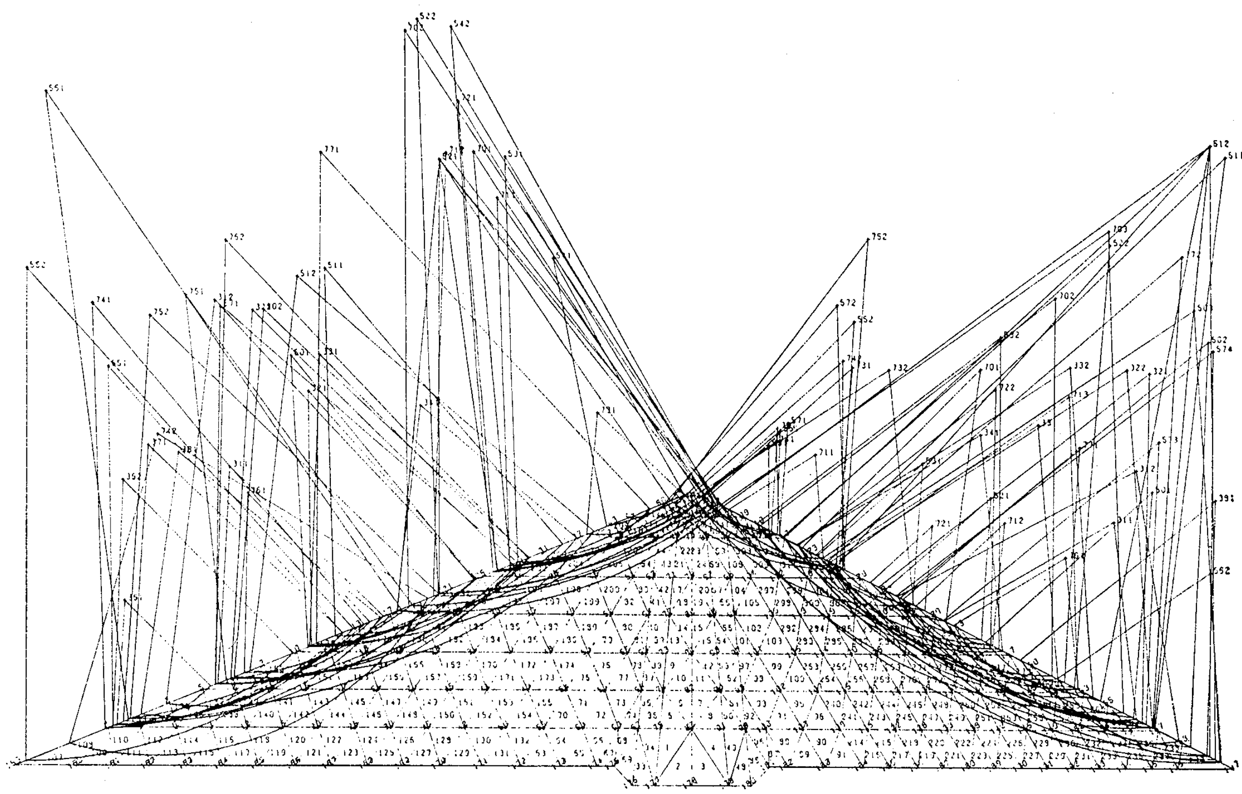

Fig. 17. Distribution of potential sliding circles

cles are to be classified into several groups upon each of which many circles concentrate. These groups can be regarded as sliding surfaces which are most possible to appear again both in many of any other seismic response analysis and at many times during an earthquake motion even in one case of analysis. Drawing a circle so as to pass through the center part of each group we obtained 17 representative potential sliding circles in Fig. 4. There are at least two reasons for that all of representative potential slides are thin. One is that the response acceleration increases remarkably at near the surface of the dam because of gradual reduction of velocity impedance. According to Sawada and Takahashi (1975), shear wave velocity of every rockfill dam is fairly low in the zone within the depth up to 5 m from surface. Another is that the materials of rock zone have usually very low cohesion, and even if the potential slides pass through the central core the length cut out by it is considerably shorter than total one so that total strength along above sliding surface becomes lower with thinner one. Though any potential slide is thin near the surface in rockfill dam, it is possible to cause some failure of the core. In many dynamic failure tests on model rockfill dams performed so far (Clough et al, 1956 ; Niwa et al, 1958 ; Tamura et al, 1975 ; Watanabe, 1977), it is usually found that the thin surface slide starts first in rock zone, then central core is exposed and broken by vibration resulting in over flow of reservoir water. Hence, it may be said that the thin surface slide in rock zone is most possible to be a trigger of the catastrophic failure in rockfill dam. Besides, from conservative viewpoint too, it had better to examine thin surface slide of rock zone prior to secondary slide in our opinion.

As for the second problem in the discussion, concerning the applicability of the proposed method to the fill dams constructed with cohesive materials, we suppose that the error in proposed method will be larger as mentioned in the paper (see pp. 6–7). Moreover, the pattern of dynamic failure must be different from that mentioned above. The part of sliding surface at near upper end must be formed by separation due to tension crack and should not be considered to have any strength. Therefore, in our opinion we had better to prepare an exact dynamic response analysis method where separating and sliding elements are introduced as stated in the paper (see pp. 7).

As for the final problem in the discussion, concerning the estimated amount of permanent displacement, it may be said that the amount of permanent displacement depends on mainly three important factors. The first is the predominant period of base earthquake motion. When it is close to natural period of dam, the value of equivalent instantaneous seismic coefficient becomes remarkably large, especially in thin surface potential sliding mass near the crest, resulting in large permanent displacement. Against shorter period, on the contrary, it becomes remarkably small in the same part. For an example as to sliding circle No. 3 which yields the maximum amount of slide through all numerical experiments in the paper, the amount of slide against the sinusoidal base motion of 0.375 (sec) in predominant period becomes less than 1/20 of the one against that of 0.625(sec) as shown in Table 2 in spite that the amplitude is kept constant. With shorter period, say 0.125(sec), there yields no zone where even local factor of safety comes to under unity though the amplitude of base motion is increased up to 600 gal as stated in reference 1). And so, it is most probable that the amount of slide comes to be fairly large against such strong motion earthquake as has long predominant period in the high rockfill dams. As for the low dams, however, theses natural periods are short so that the amount of slide will be considerably small, though near in resonance, because of short duration of sliding. The second is dynamic strength of rock materials. As stated in reference 10), the dynamic strength of rock materials under 2.5 % of permitting residual strain comes to be 5 to 25% larger than static one. In spite of that static strength was applied to the analyses in the paper so as to estimate the amount of slide in conservative side. The third is the method of analysis, say the decoupled analysis where the permanent displacements are calculated separately from dynamic analysis, as pointed out in the discussion. It is supposed that the response acceleration in continuous numerical model must be somewhat larger than in an exact dynamic response analysis model previously mentioned during sliding. And above must be checked by an exact method as stated in the paper (see pp. 6–7), though the effects of above mentioned two factors on the amount of slide are very large. In any way, it may be said that the proposed method is restricted to conservative side in the estimation of the amount of slide.

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